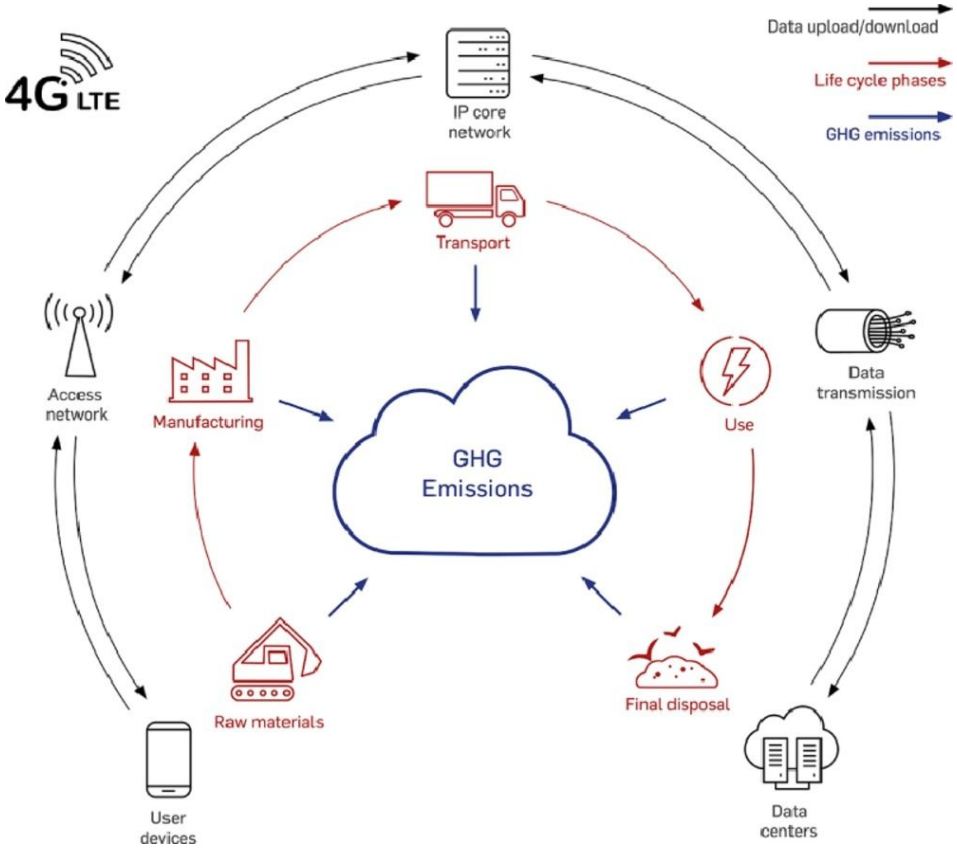
ICT are 4.500 million years old

eva.vidal@upc.edu



D. Ruiz, G. San Miguel, J. Rojo, J.G. Teriús-Padrón, E. Gaeta, M.T. Arredondo, J.F. Hernández, J. Pérez, **Life cycle inventory and carbon footprint assessment of wireless ICT networks for six demographic areas**, Resources, Conservation and Recycling, Volume 176, 2022

https://www.sciencedirect.com/science/article/pii/S0921344921005607

Carbon footprint of wireless ICT networks

Between
81 and 103 kg CO2 eq./subscription/year

 1 elm~ 22 kg CO_{2eq} /year ~ 2 kg CO_{2eq} /month ~ 60 g CO_{2eq} /day

Between
🌳🌳🌳🌳 and 🌳🌳🌳🌳🌳 elms
by subscription/year

https://www.sciencedirect.com/science/article/pii/S0921344921005607

Costs associated with the ICT life cycle:

- Manufacture
- Use
- End-of-life

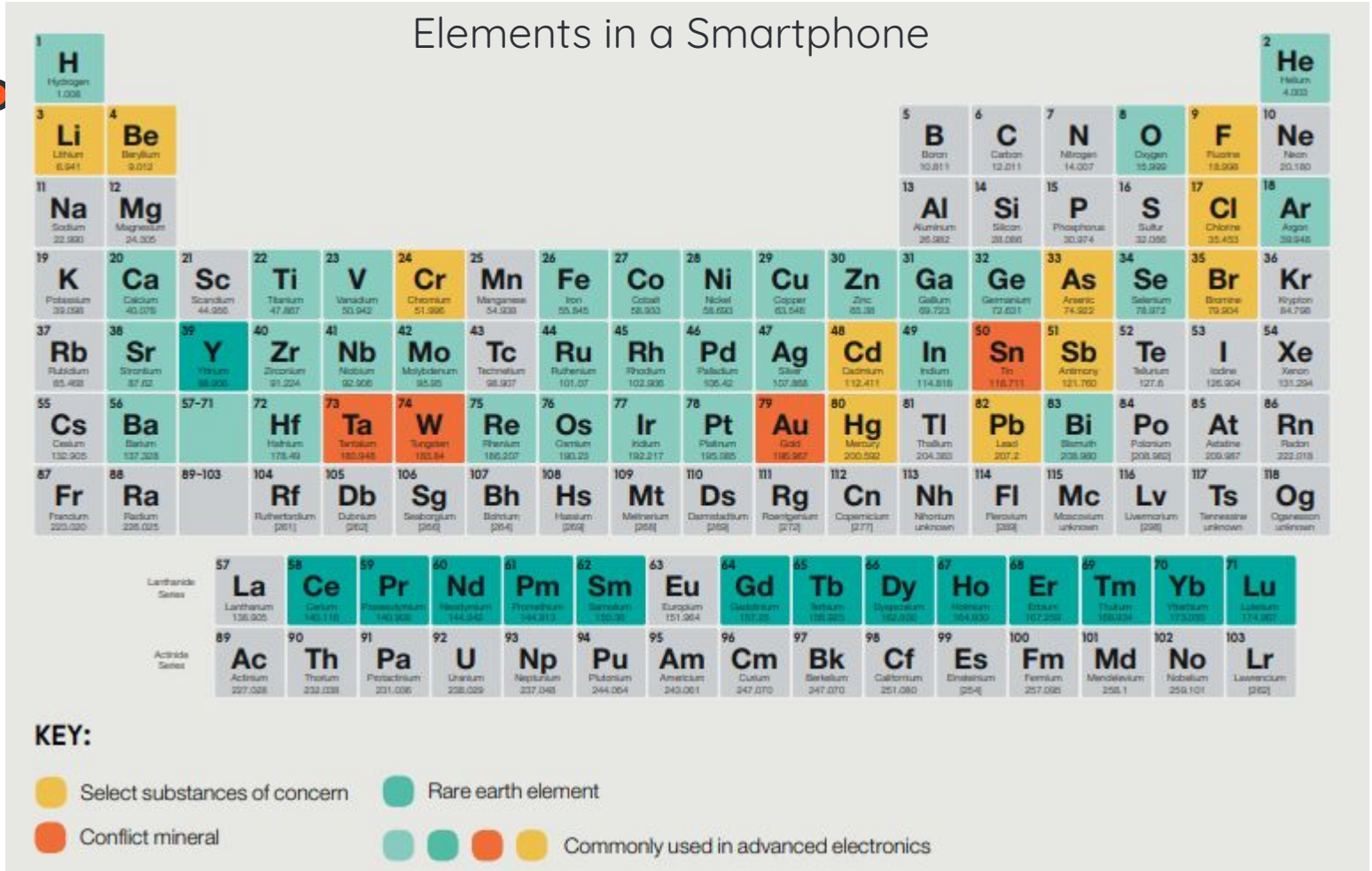
- Costs associated with the ICT life cycle:

- **Manufacture**

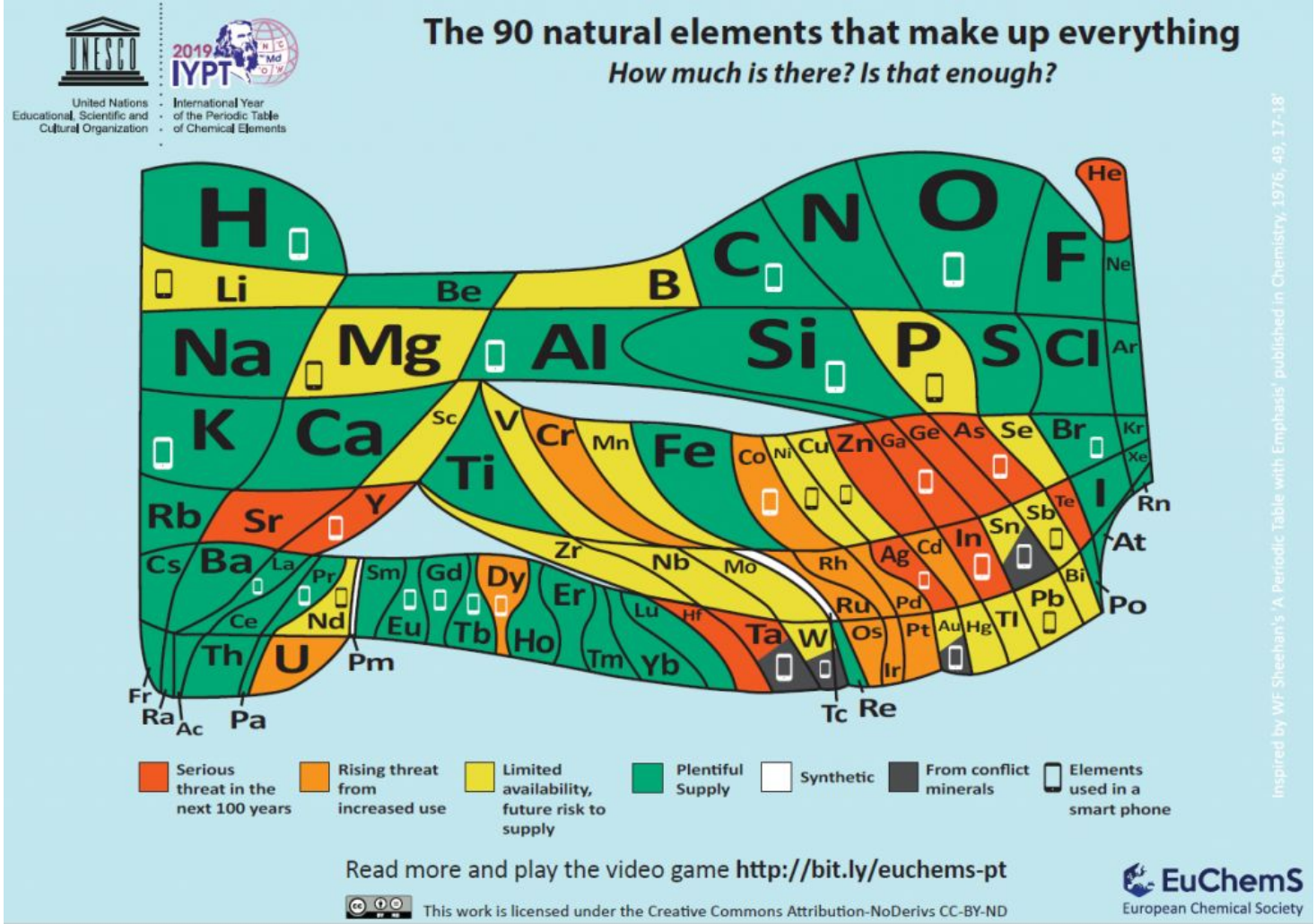
  Use

  End-of-life

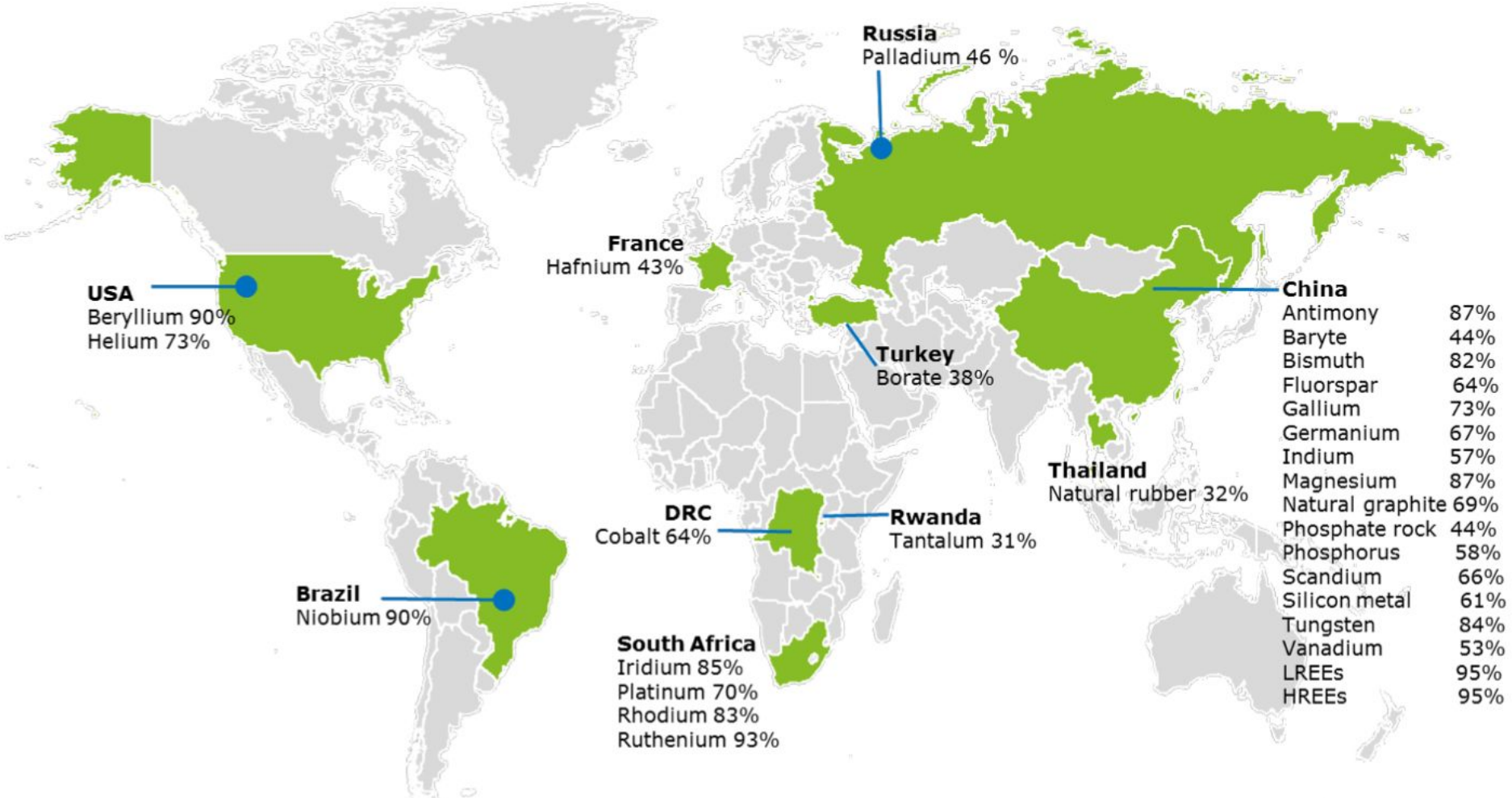
Elements in a Smartphone



Source: https://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf

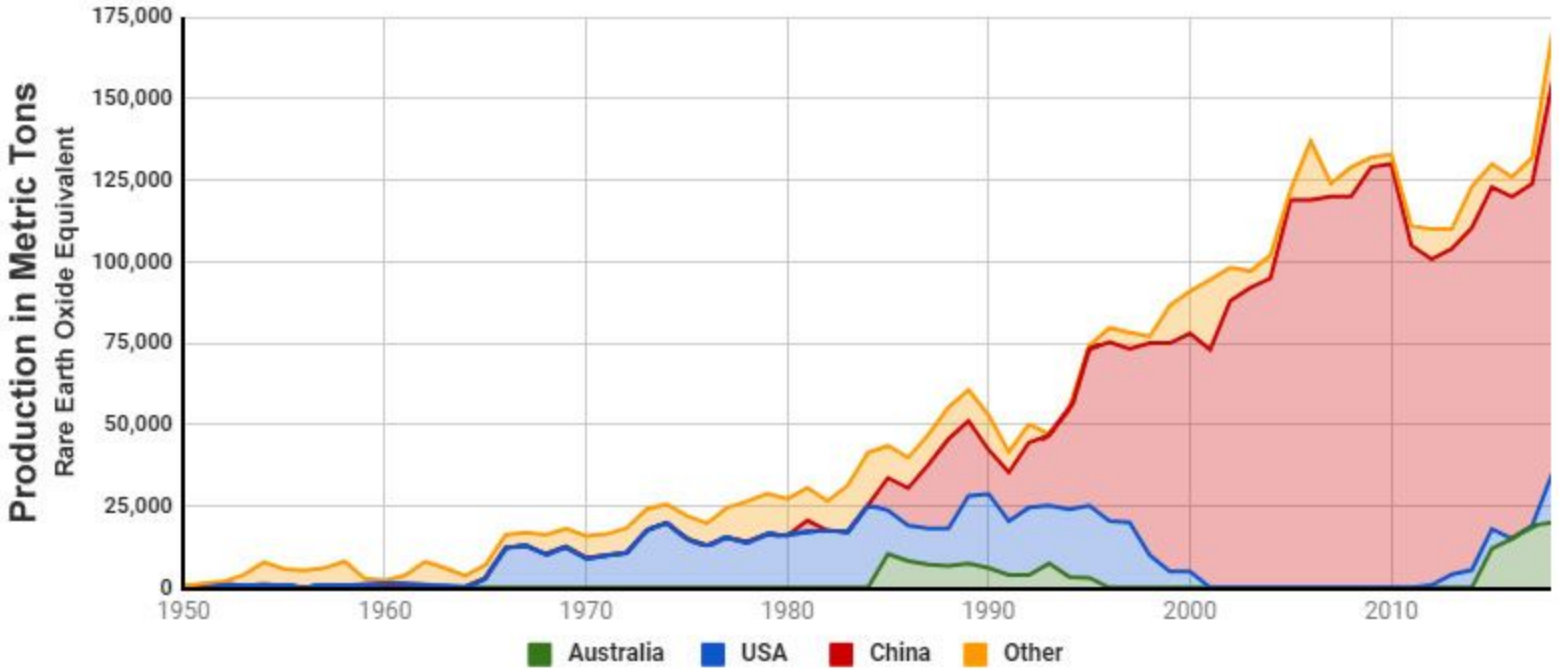

United Nations Educational, Scientific and Cultural Organization
2019 IYPT
International Year of the Periodic Table of Chemical Elements
The 90 natural elements that make up everything
How much is there? Is that enough?
Serious threat in the next 100 years
Rising threat from increased use
Limited availability, future risk to supply
Plentiful Supply
Synthetic
From conflict minerals
Elements used in a smart phone
Inspired by WF Sheehan's 'A Periodic Table with Emphasis' published in Chemistry, 1976, 49, 17-18'
Read more and play the video game http://bit.ly/euchems-pt
This work is licensed under the Creative Commons Attribution-NoDerivs CC-BY-ND
EuChemS
European Chemical Society

https://ejatlas.org/conflict/congo-coltan-in-the-kivu-region-dr-of-congo



https://op.europa.eu/en/publication-detail/-/publication/08fdab5f-9766-11e7-b92d-01aa75ed71a1/language-en/format-PDF/source-search, p. 15.

And China is now prioritizing its own industries and market



https://geology.com/articles/rare-earth-elements/

https://www.businessinsider.com/photos-of-chinese-rare-earth-mining-2013-4?op=1#china-accounts-for-about-97-percent-of-the-worlds-supply-of-rare-earths-1

Rare earth mining in China: the bleak social and environmental costs

China produces 85% of global supply of the 17 chemically similar elements crucial to smartphone, camera lens and magnet manufacture – and half that output is from the city of Baotou

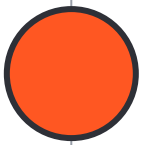
A worker pours rare earth metal Lanthanum into a mould near the town of Damao, in China's Inner Mongolia Autonomous Region. Photograph: David Gray/REUTERS

https://www.theguardian.com/sustainable-business/rare-earth-mining-china-social-environmental-costs

Refining one ton of rare earth elements

=

75,000 liters of acidic water and one ton of radioactive residue



Embodied energy

Carbon footprint	
13-inch MacBook Air with Retina display	
1.6GHz Processor with 128GB Storage	176 kg CO_2e
1.6GHz Processor with 256GB Storage	198 kg CO_2e

13-inch MacBook Air with Retina display life cycle carbon emissions

77%	Production
17%	Transport
6%	Use
<1%	End-of-life processing

https://www.apple.com/euro/environment/pdf/a/generic/products/notebooks/13-inch_MacBookAir_w_Retina_PER_oct2018.pdf

[3] Greenhouse gas emissions were calculated using a life cycle assessment methodology in accordance with ISO 14040 and 14044 standards and based on the iPhone 11 64GB memory configuration.

Configuration	Carbon footprint iPhone 11
64GB	72 kg CO_2e
128GB	77 kg CO_2e
256GB	89 kg CO_2e

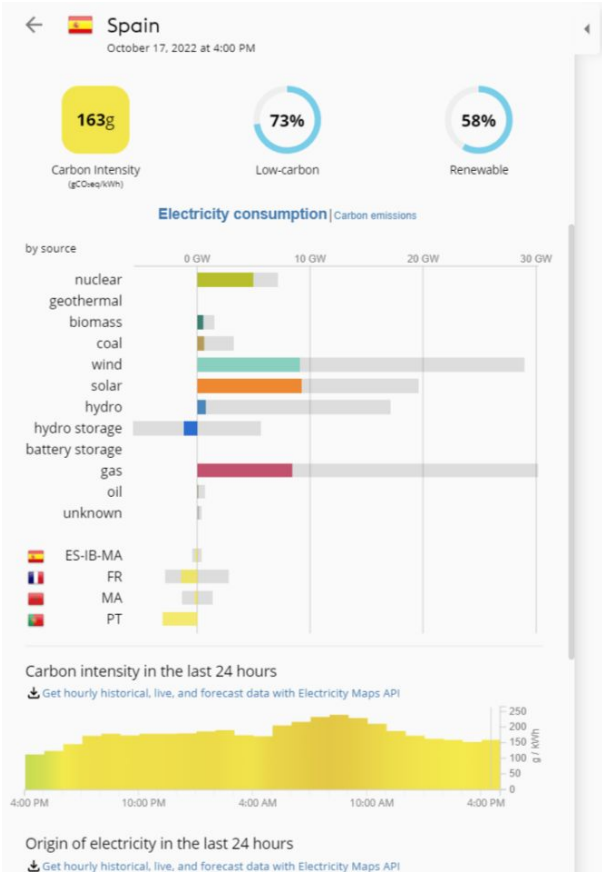
iPhone 11 life cycle carbon emissions

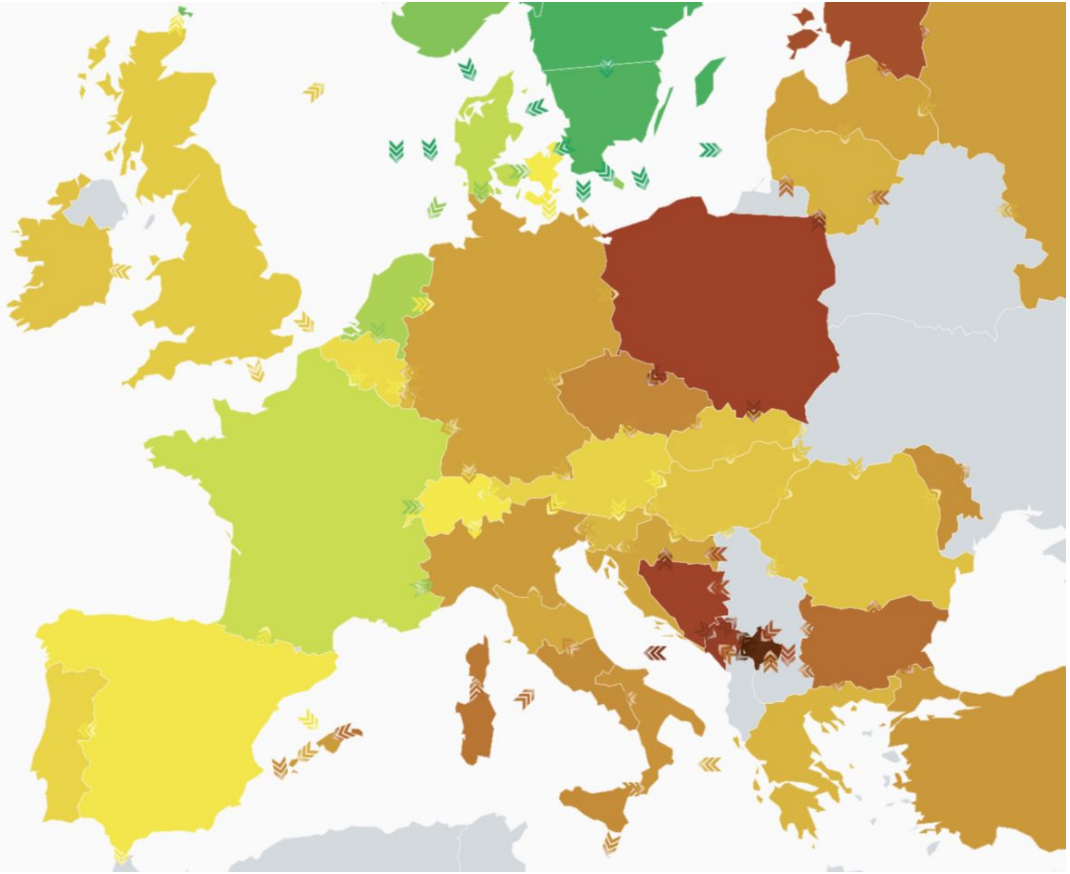
79%	Production
3%	Transport
17%	Use
<1%	End-of-life processing

https://www.apple.com/th/environment/pdf/products/iphone/iPhone_11_PER_sept2019.pdf

Why is so energetically costly to manufacture an IC?

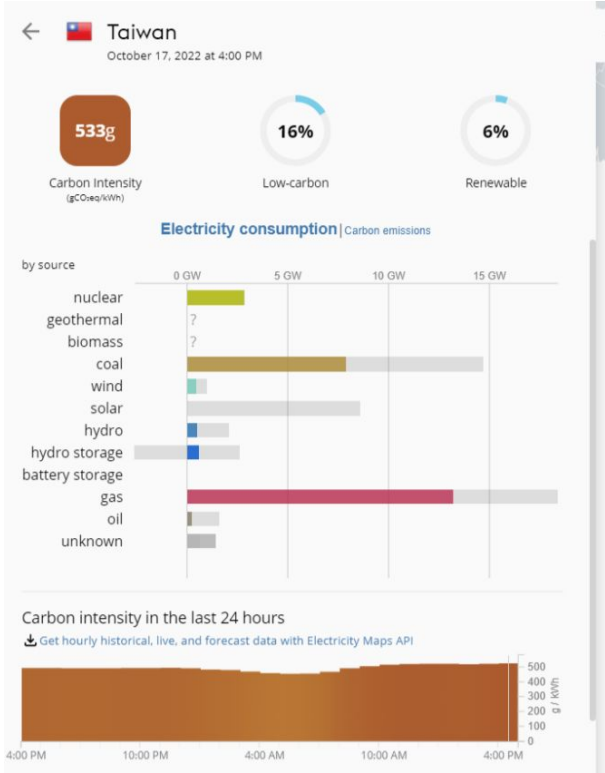
- Second Law of thermodynamics
    - Size matters
- Tidying up requires a lot of energy





https://app.electricitymaps.com/

@evavidaleva



https://app.electricitymaps.com/

@evavidaleva

https://www.businessinsider.com/photos-indias-illegal-coal-mines-2012-10#a-miner-makes-his-way-through-one-such-tunnel-at-a-mine-in-the-district-of-jaintia-hills-meghalaya-india-6

@evavidaleva

https://www.businessinsider.com/photos-indias-illegal-coal-mines-2012-10#indias-coal-demand-currently-totals-700-million-tonnes-and-is-expected-to-reach-1-billion-tonnes-by-2017-the-government-needs-to-implement-major-reforms-to-curb-

@evavidaeva

We also have good news:

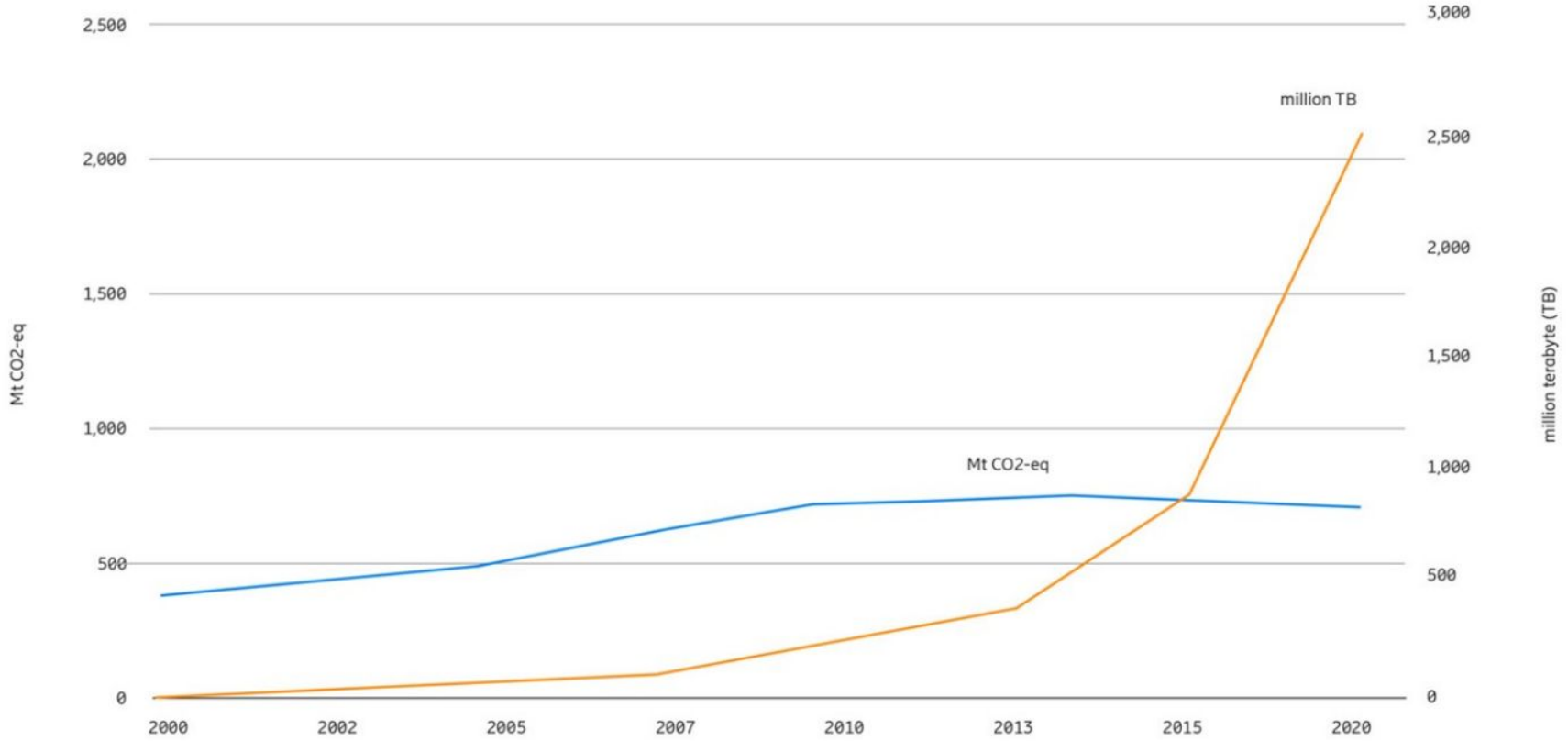
GOOD NEWS: Koomey's law

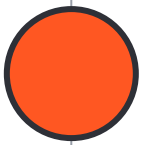
Energy efficiency of computing has doubled roughly every 1.6 years since the 1940s – and every 2.7 years since 2000.

In data transmission networks, energy intensity has halved every two years since 2000.

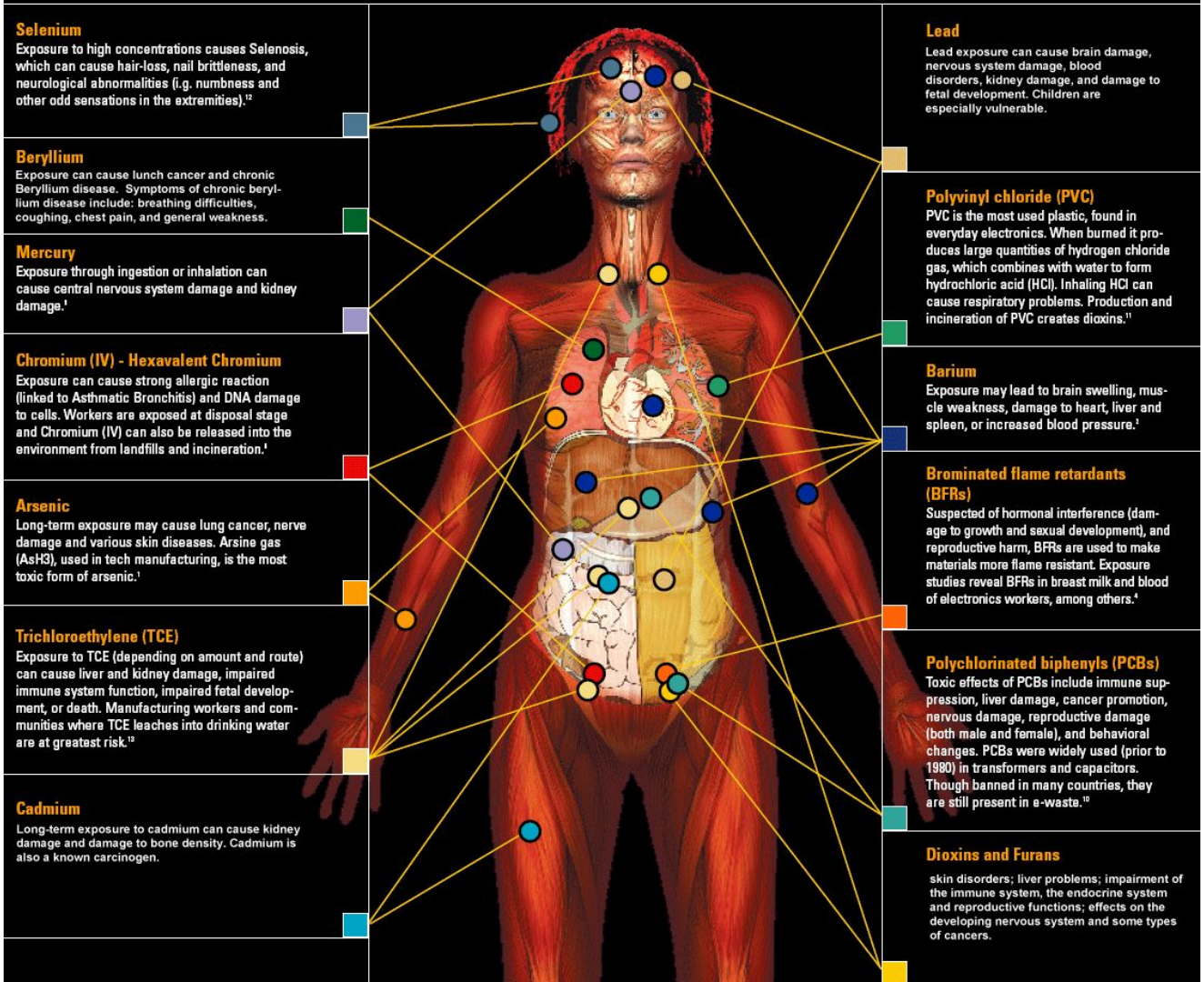
https://ieeexplore.ieee.org/document/5440129

Carbon Footprint of ICT and data traffic development



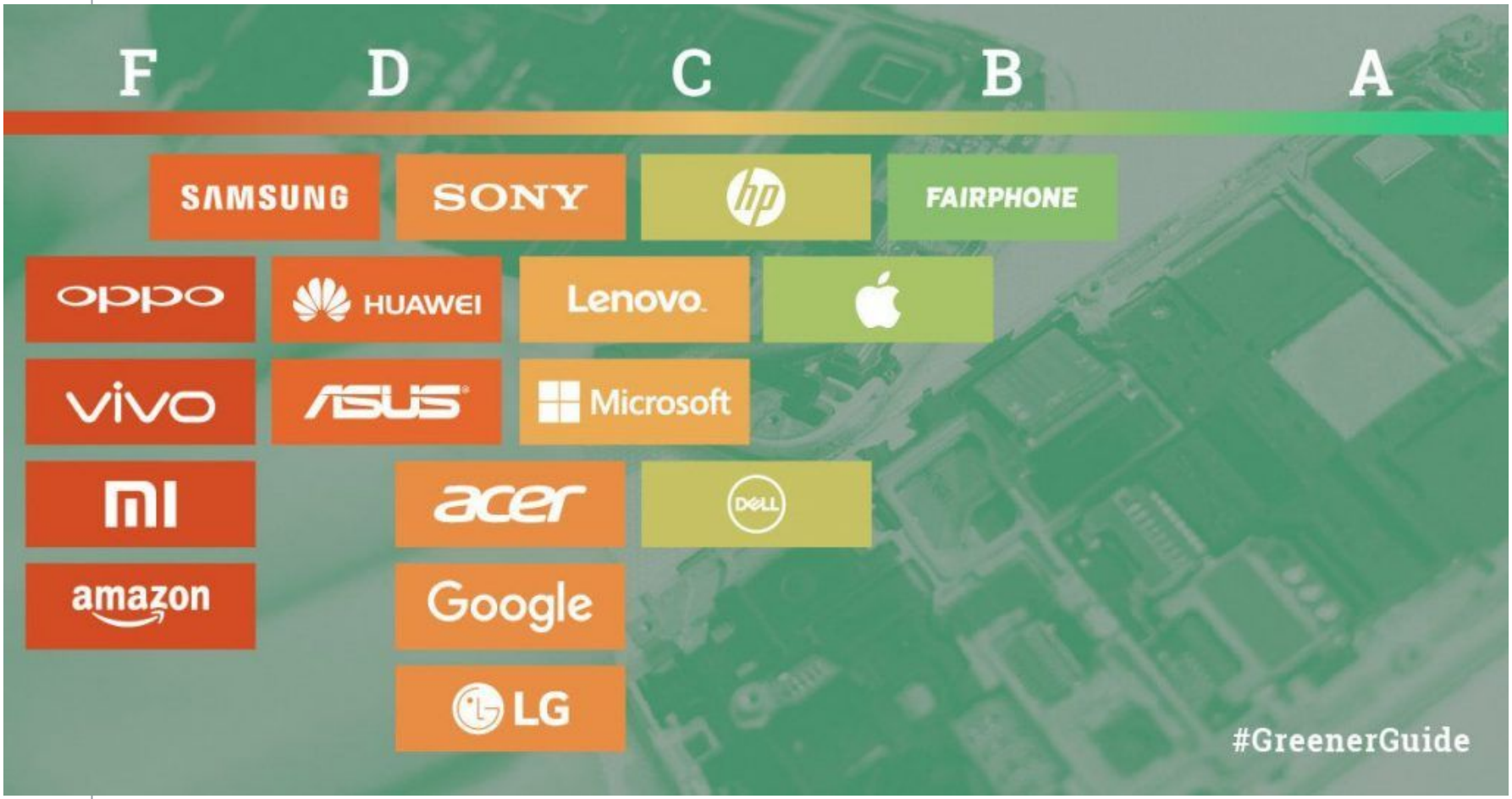


Health problems?


Selenium
Exposure to high concentrations causes Selenosis, which can cause hair-loss, nail brittleness, and neurological abnormalities (i.g. numbness and other odd sensations in the extremities).[12]
Beryllium
Exposure can cause lunch cancer and chronic Beryllium disease. Symptoms of chronic beryllium disease include: breathing difficulties, coughing, chest pain, and general weakness.
Mercury
Exposure through ingestion or inhalation can cause central nervous system damage and kidney damage.[1]
Chromium (IV) - Hexavalent Chromium
Exposure can cause strong allergic reaction (linked to Asthmatic Bronchitis) and DNA damage to cells. Workers are exposed at disposal stage and Chromium (IV) can also be released into the environment from landfills and incineration.[1]
Arsenic
Long-term exposure may cause lung cancer, nerve damage and various skin diseases. Arsine gas (AsH3), used in tech manufacturing, is the most toxic form of arsenic.[1]
Trichloroethylene (TCE)
Exposure to TCE (depending on amount and route) can cause liver and kidney damage, impaired immune system function, impaired fetal development, or death. Manufacturing workers and communities where TCE leaches into drinking water are at greatest risk.[13]
Cadmium
Long-term exposure to cadmium can cause kidney damage and damage to bone density. Cadmium is also a known carcinogen.
Lead
Lead exposure can cause brain damage, nervous system damage, blood disorders, kidney damage, and damage to fetal development. Children are especially vulnerable.
Polyvinyl chloride (PVC)
PVC is the most used plastic, found in everyday electronics. When burned it produces large quantities of hydrogen chloride gas, which combines with water to form hydrochloric acid (HCl). Inhaling HCl can cause respiratory problems. Production and incineration of PVC creates dioxins.[11]
Barium
Exposure may lead to brain swelling, muscle weakness, damage to heart, liver and spleen, or increased blood pressure.[1]
Brominated flame retardants (BFRs)
Suspected of hormonal interference (damage to growth and sexual development), and reproductive harm, BFRs are used to make materials more flame resistant. Exposure studies reveal BFRs in breast milk and blood of electronics workers, among others.[4]
Polychlorinated biphenyls (PCBs)
Toxic effects of PCBs include immune suppression, liver damage, cancer promotion, nervous damage, reproductive damage (both male and female), and behavioral changes. PCBs were widely used (prior to 1980) in transformers and capacitors. Though banned in many countries, they are still present in e-waste.[10]
Dioxins and Furans
skin disorders; liver problems; impairment of the immune system, the endocrine system and reproductive functions; effects on the developing nervous system and some types of cancers.

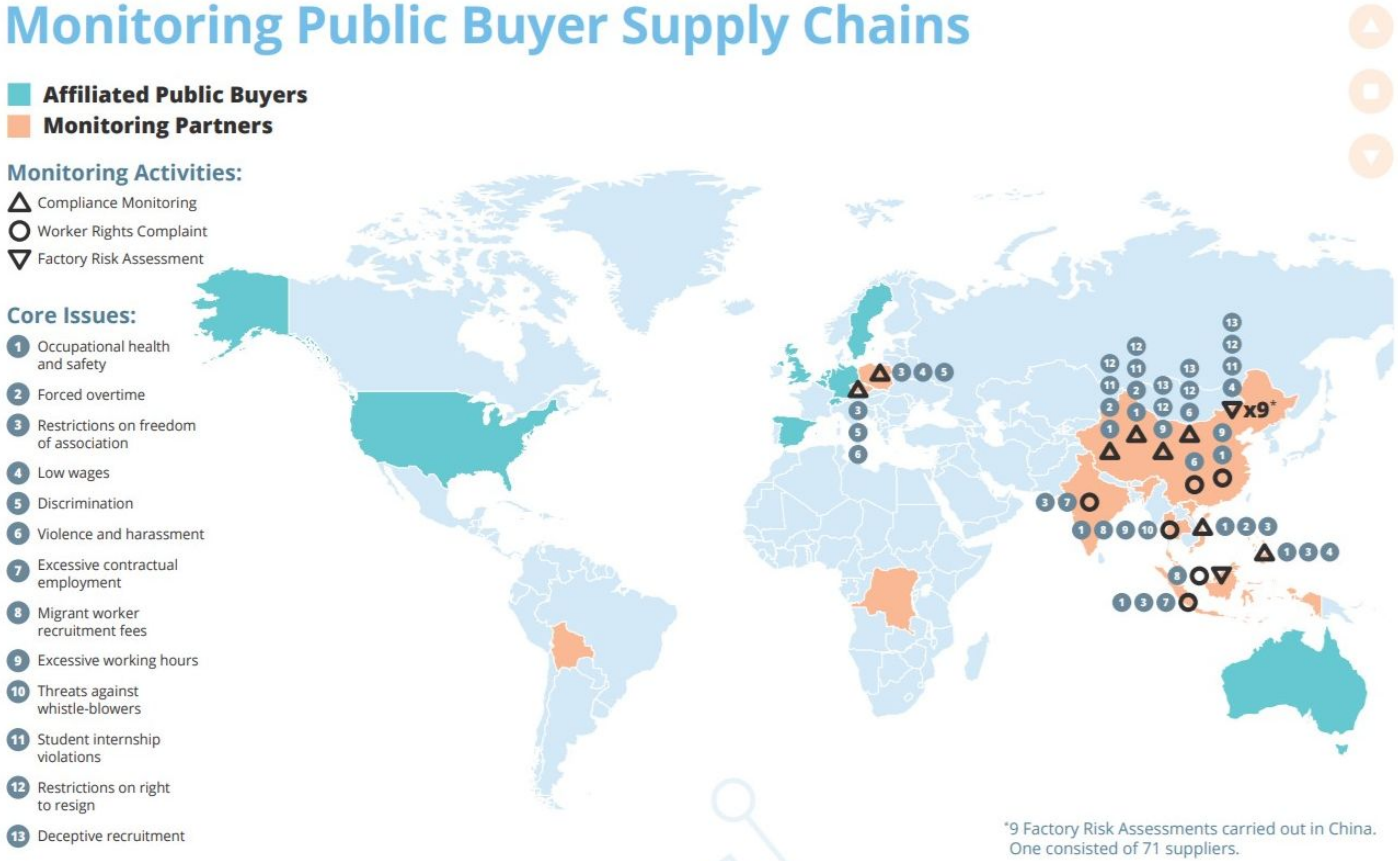
https://www.caixinglobal.com/2017-07-27/foxconns-hefty-us-investment-will-have-limited-impact-on-china-analysts-say-101123086.html

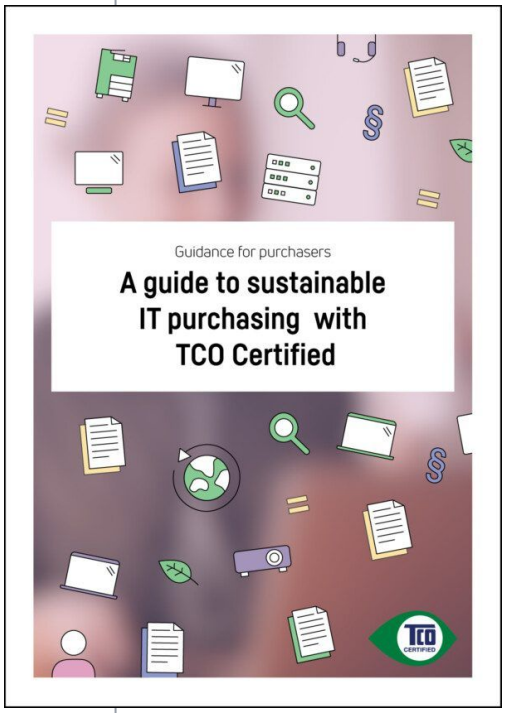
What can we do?



https://www.greenpeace.org/usa/reports/greener-electronics-2017/

Monitoring Public Buyer Supply Chains





https://tcocertified.com/step-by-step-guide-for-purchasers/

Conflict minerals

> LEARN MORE

Social responsibility

> LEARN MORE

Hazardous substances

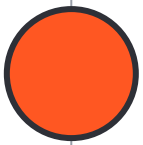
> LEARN MORE

Electronic waste

> LEARN MORE

Circular economy

> LEARN MORE



So far...

Average life cycle in kgCO2-eq.

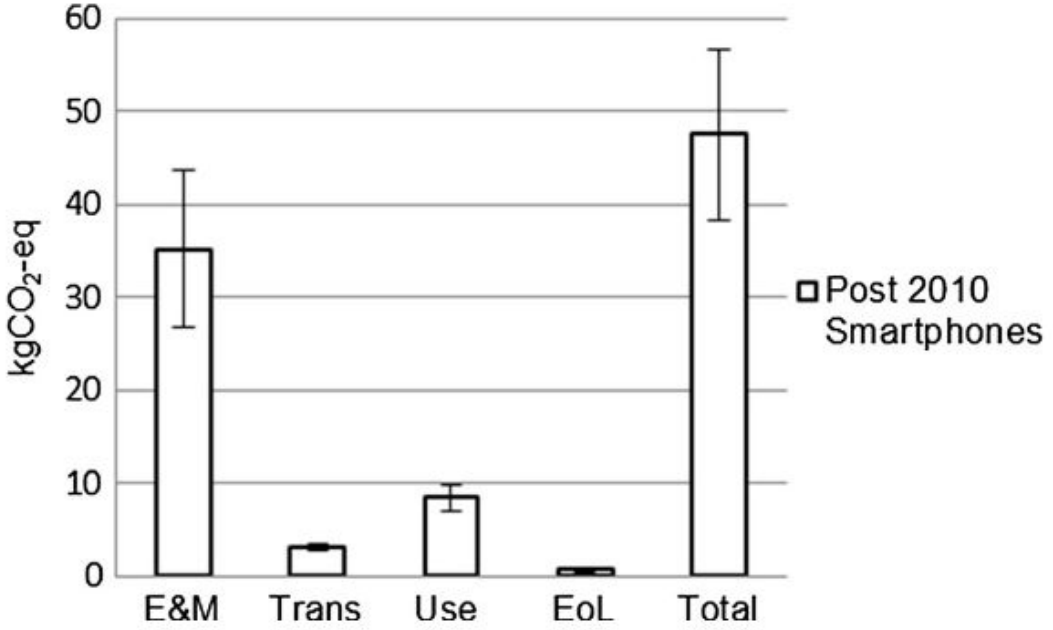


Fig. 2 Averaged life cycle phase distribution for smartphones made after 2010

Redefining scope: the true environmental impact of smartphones?
Suckling J Lee J
International Journal of Life Cycle Assessment
Publisher: Springer Verlag
2015 vol: 20 (8) pp: 1181–1196

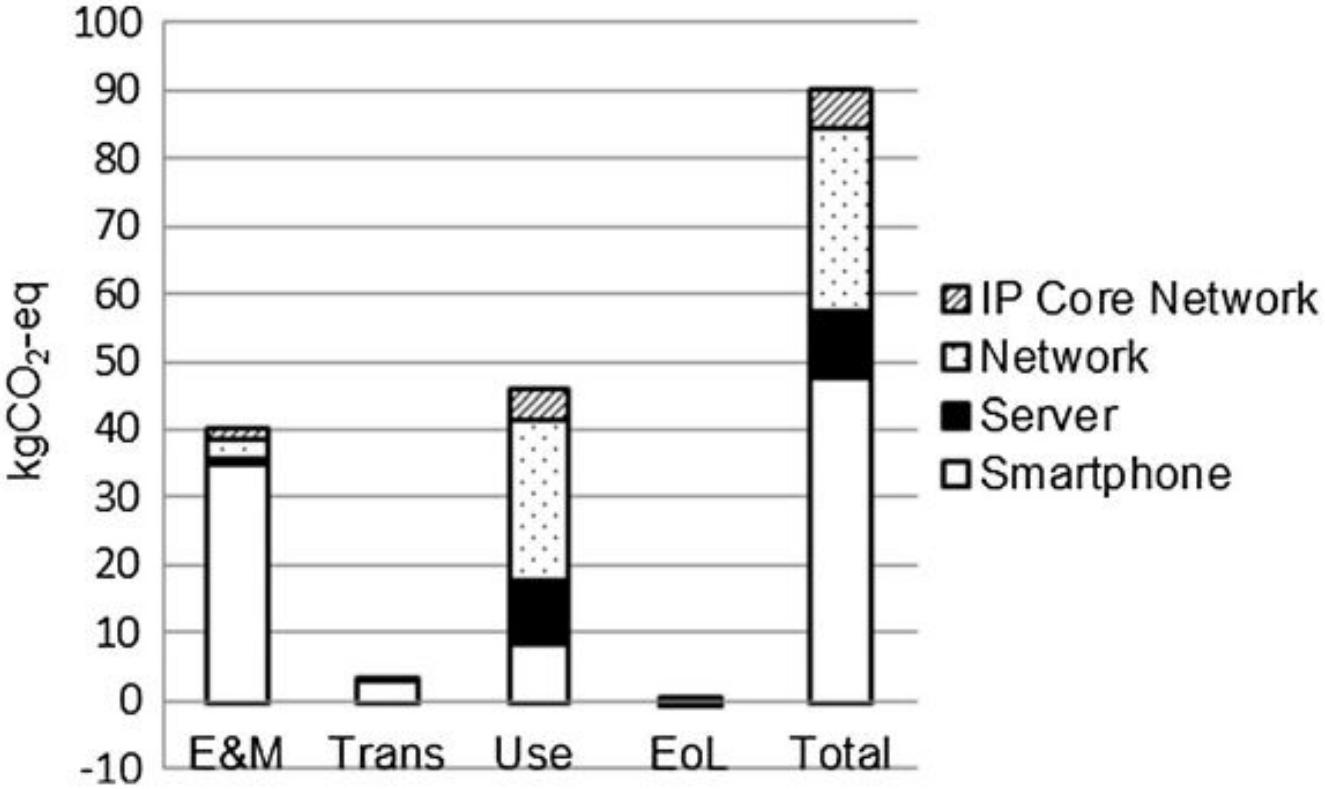


Fig. 5 GHG emissions across the life cycle of a smartphone (*white*) including contribution from a rack server (*black*), network (*dots*) and IP core network (*diagonal hashing*)

- Costs associated with the ICT life cycle:

- Manufacture
- **Use**
- End-of-life

Trees to be planted to offset the pollution caused by:

- 1.9 trillion yearly searches on Google: **$16 \cdot 10^6$ trees**
- Data US citizens consumed in 2019: **$231 \cdot 10^6$ trees**
- email spam: **$1.6 \cdot 10^9$ trees**

Netflix vs EU flights and EU cars

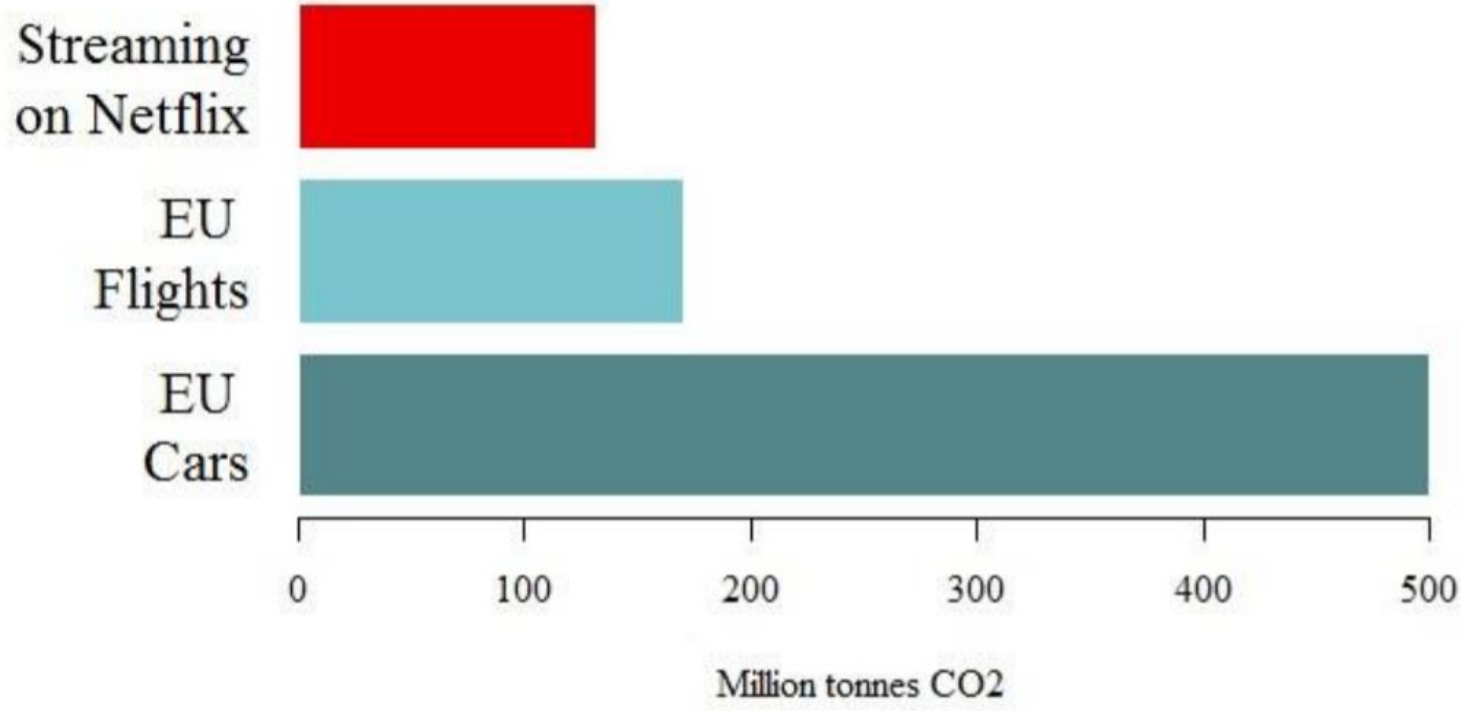
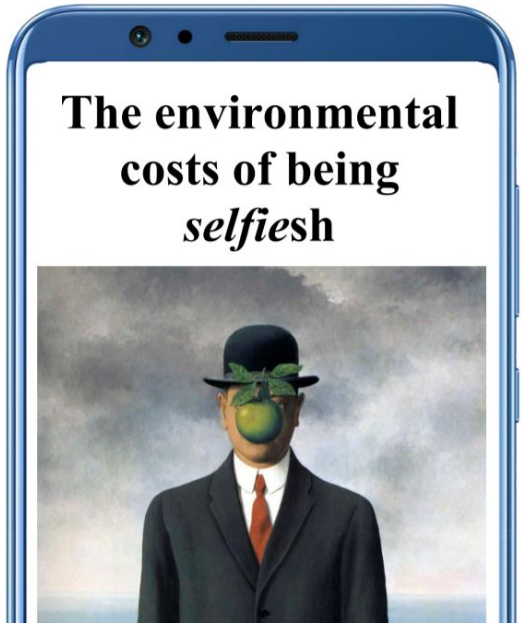
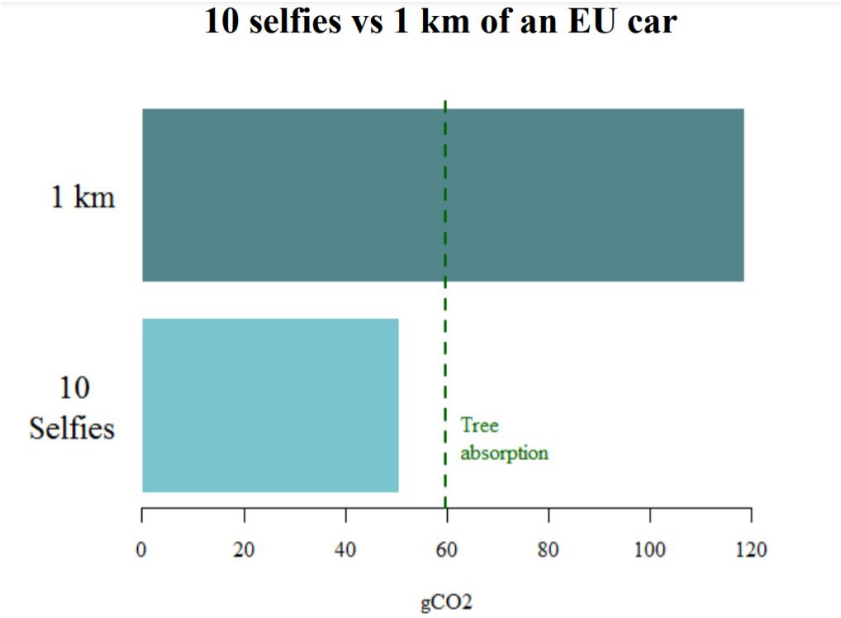


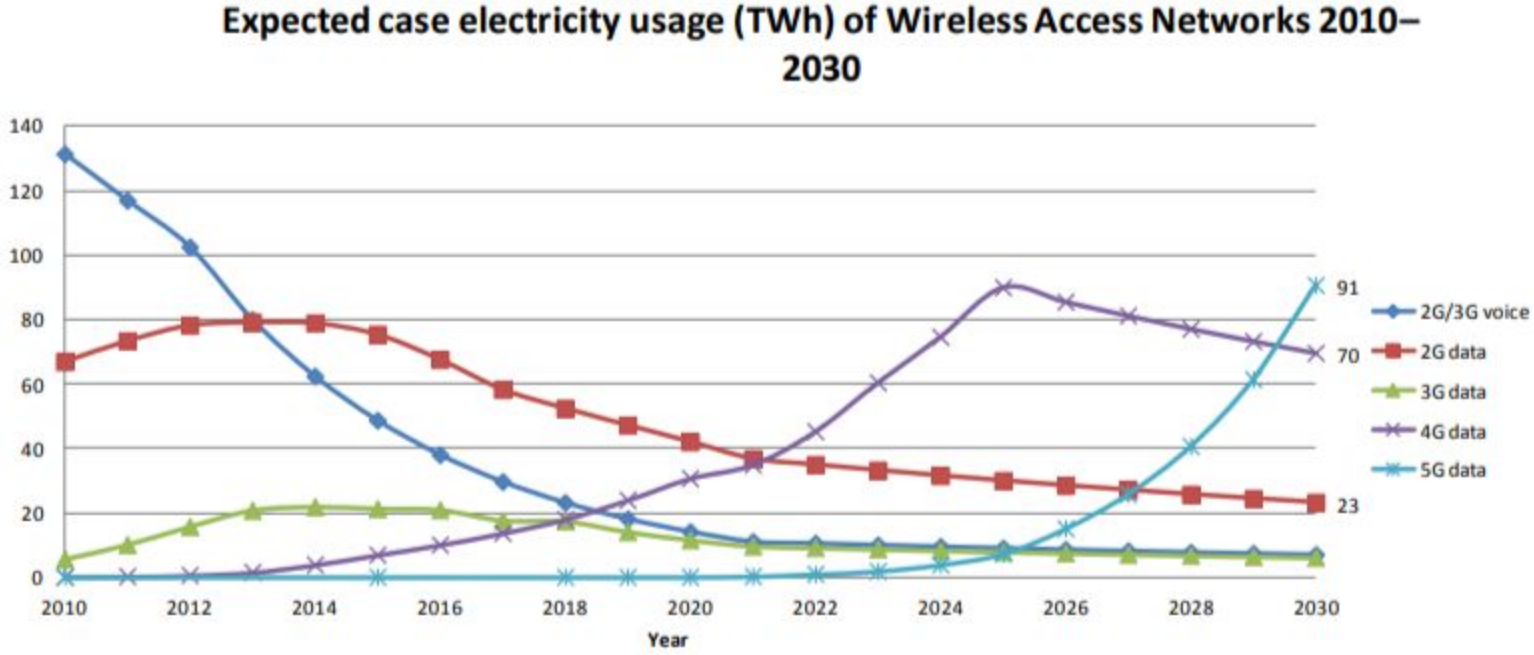
Fig. 6: *The amount of CO_2 emitted by Netflix, all EU cars and all EU flights, in one year. Sources: Netflix Media Center, European Environment Agency (2019), European Aviation Safety Agency (2016).*

https://www.core-econ.org/wp-content/uploads/2019/07/Data-competition-selfie.pdf





https://www.core-econ.org/wp-content/uploads/2019/07/Data-competition-selfie.pdf


Expected case electricity usage (TWh) of Wireless Access Networks 2010–2030
140
120
100
80
60
40
20
0
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
Year
91
70
23
2G/3G voice
2G data
3G data
4G data
5G data

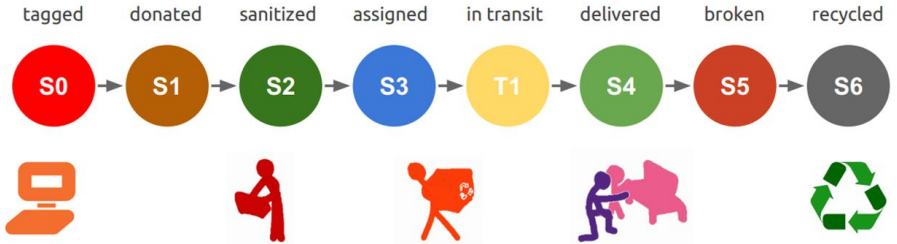
- Costs associated with the ICT life cycle:

- Manufacture
  Use
  End-of-life


Aesthetic obsolescence!!!!!!!!

R Reuse R

- Examples:
  - Tecnologia x Tothom: https://txt.upc.edu/
  - Programa Reutilitza UPC: https://reutilitza.upc.edu/ca
  - Labdoo: https://www.labdoo.org/
  - NascoICT: http://nascoict.org/ca/
  - Ereuse: https://www.ereuse.org/

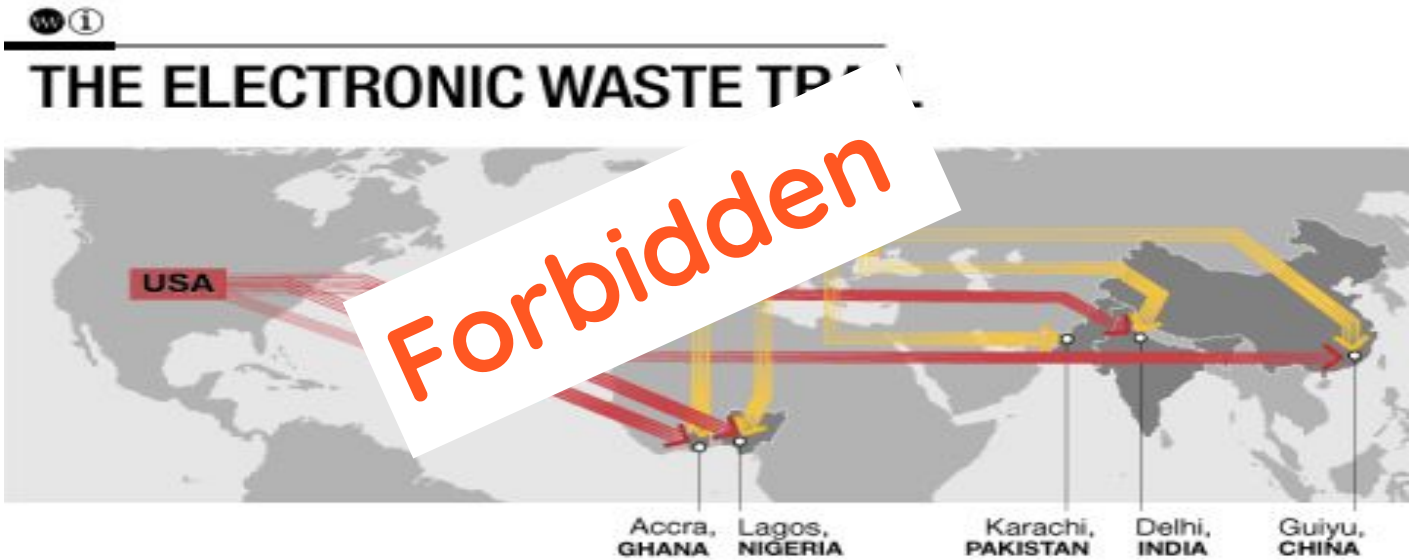


Only a small part (<25%) is recycled

The least dangerous

But even the best garbage dumps can not avoid leaking heavy or poisonous elements

Traffic?



Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal

The logo of the Basel Convention Secretariat

Type	United Nations treaty
Signed	22 March 1989[1]
Location	Basel, Switzerland[1]
Effective	5 May 1992[1]
Condition	Ninety days after the ratification by at least 20 signatory states[1]
Signatories	53[1]
Parties	186[1]
Depositary	Secretary-General of the United Nations
Languages	Arabic, Chinese, English, French, Russian, Spanish

Basel Convention at Wikisource

http://www.basel.int/

AUCOOP

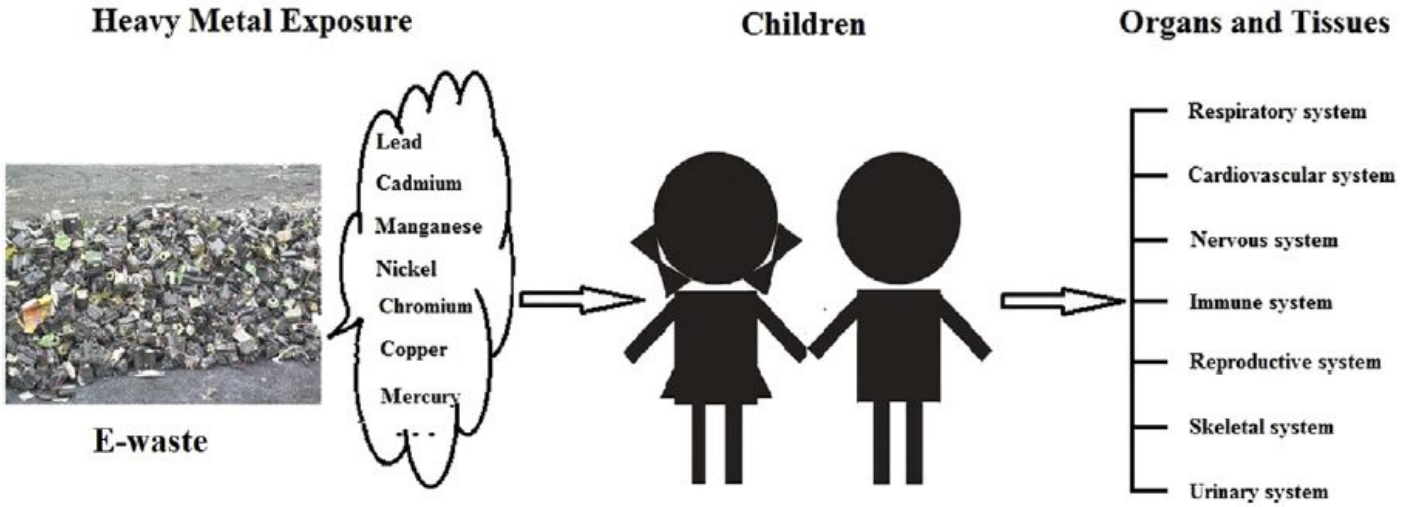
https://aucoop.upc.edu/


Uncle Sam

Children with health impairments by heavy metals in an e-waste recycling area

Xiang Zeng [a, b, c], Xijin Xu [a, d], H.Marike Boezen [b, c], Xia Huo [e, *]

[a] Laboratory of Environmental Medicine and Developmental Toxicology, and Guangdong Provincial Key Laboratory of Infectious Diseases and Molecular Immunopathology, Shantou University Medical College, Shantou University, 22 Xinling Road, Shantou 515041, China
[b] Department of Epidemiology, University Medical Center Groningen, University of Groningen, 1 Hanzeplein, Groningen 9700RB, The Netherlands
[c] Groningen Research Institute for Asthma and COPD (GRIAC), University Medical Center Groningen, University of Groningen, 1 Hanzeplein, Groningen 9700RB, The Netherlands
[d] Department of Cell Biology and Genetics, Shantou University Medical College, Shantou University, 22 Xinling Road, Shantou 515041, China
[e] School of Environment, Guangzhou Key Laboratory of Environmental Exposure and Health, Guangdong Key Laboratory of Environmental Pollution and Health, Jinan University, Guangzhou 510632, China



recycling can be a business!

URBAN MINING

Materials Daisy has the potential to recover for every 100,000 iPhone devices:

Aluminum 1900 kg
Gold 0.97 kg
Silver 7.5 kg
Rare Earths 11 kg
Tungsten 93 kg
Copper 710 kg
Palladium 0.10 kg
Tin 42 kg
Cobalt 770 kg
Tantalum 1.8 kg

https://www.apple.com/lae/environment/resources/

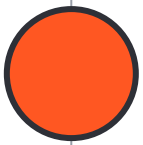
How to address sustainability

Reduce **R**euse **R**ecycle: RRR

R: Rethink!!!

“Te prometo un móvil más barato“

Economía Circular: descubre lo que es antes de que reviente el Planeta. #EconomíaCircular



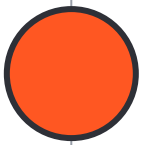
What can we do?

Precautionary principle

- The need for the decision-maker to anticipate the damage that an action can cause before it occurs.

  Whoever proposes the action has to demonstrate that it will not cause harm or that it is very unlikely that it will cause it.

- The proportionality between risk and costs and feasibility of the proposed action.



How to Rethink IT's Business Model?

1: Take Responsibility for the Supply Chain Footprint

- Greater Transparency
- Reduce Supply Chain GHG Emissions and Transition to Renewable Energy
- Moving Beyond the Audit

https://www.greenpeace.org/usa/reports/greener-electronics-2017/

2: Design Sustainable Products

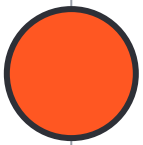
- Design for the Planet
- Eliminate Hazardous Chemicals
- Use Recycled and Recyclable Materials

https://www.greenpeace.org/usa/reports/greener-electronics-2017/

3: Take Responsibility for End-of-Life Chain

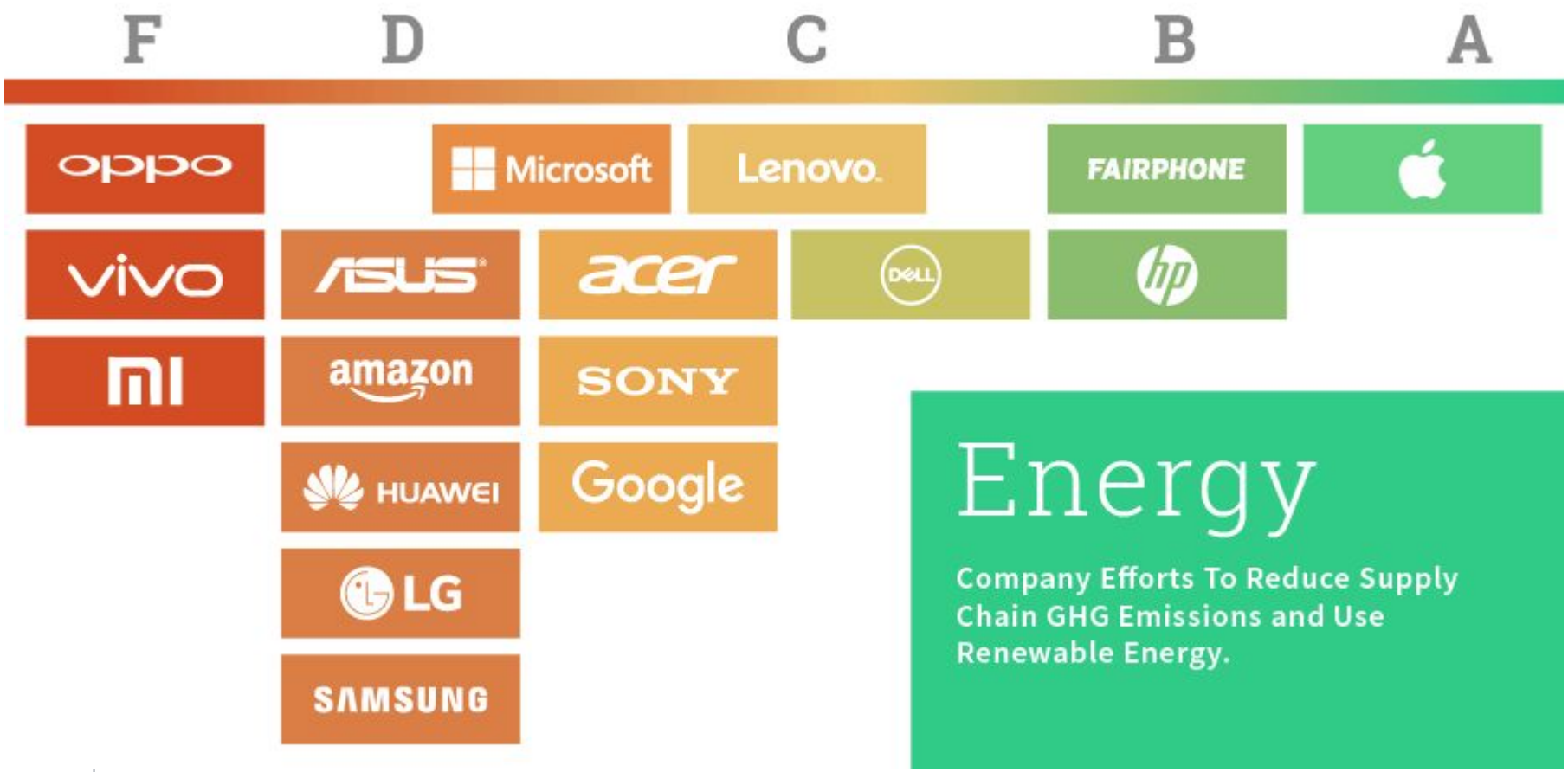
- Refurbish Devices and Components
- Strengthen Take-back Systems
- Improve Recycling Technology

https://www.greenpeace.org/usa/reports/greener-electronics-2017/

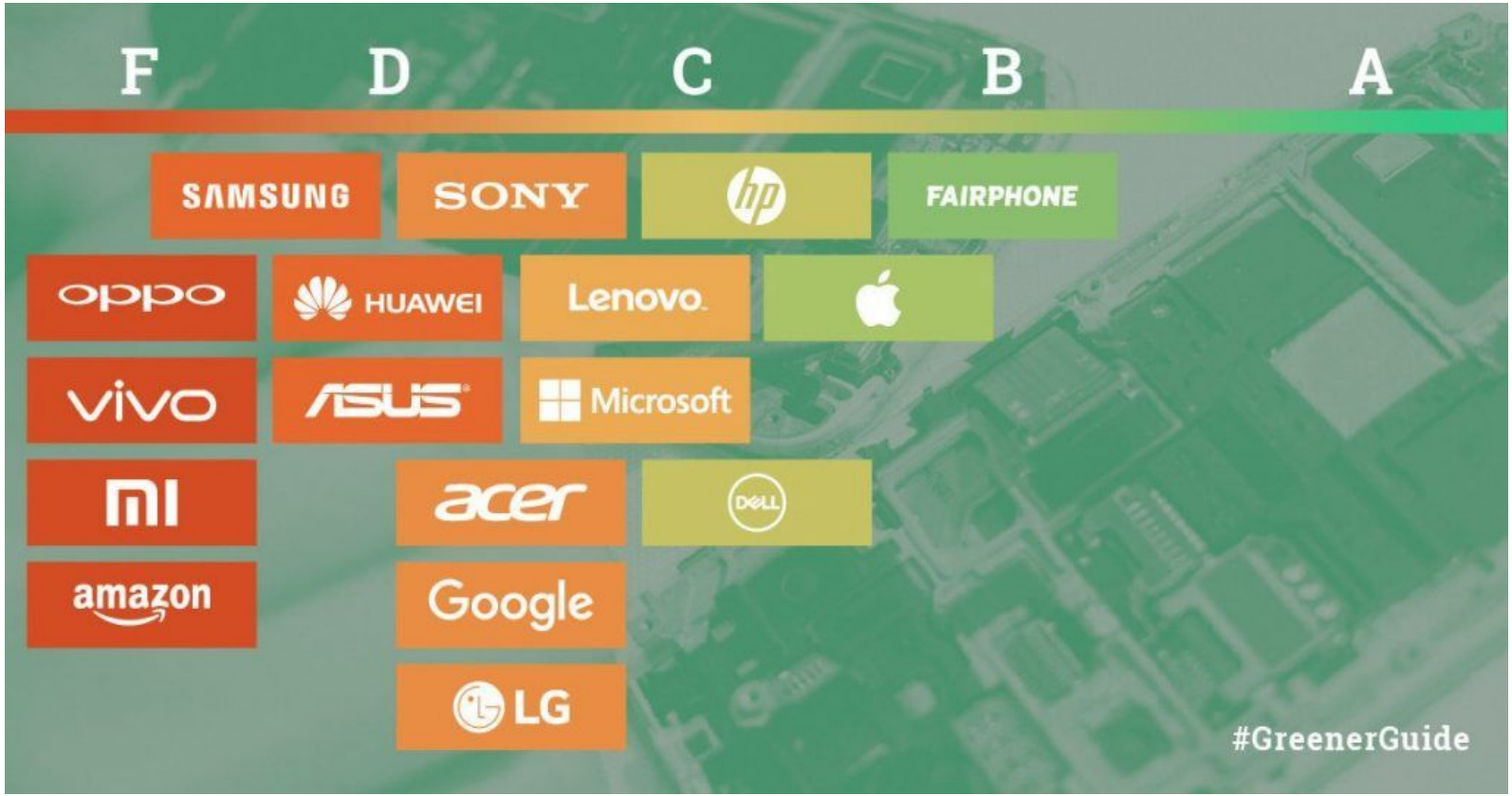


What can we do?

From the user point of view



https://www.greenpeace.org/usa/reports/greener-electronics-2017/



https://www.greenpeace.org/usa/reports/greener-electronics-2017/

Tech Company Climate Commitments Comparison

Company	2018 Carbon Footprint (MtCO2e)	Renewable Energy Matching Deadline	Fossil Fuel Phase Out Deadline	Reliant on Unbundled RE Credits?	Supply Chain Emission Reduction goal?	AI for Oil Contracts?
aws	44.4	2030[i]	None	Yes	No	Yes
Microsoft	17.6	2025	None	No	Yes	Yes
Google	15	2017	Ongoing[ii]	No	Yes	Yes[iii]

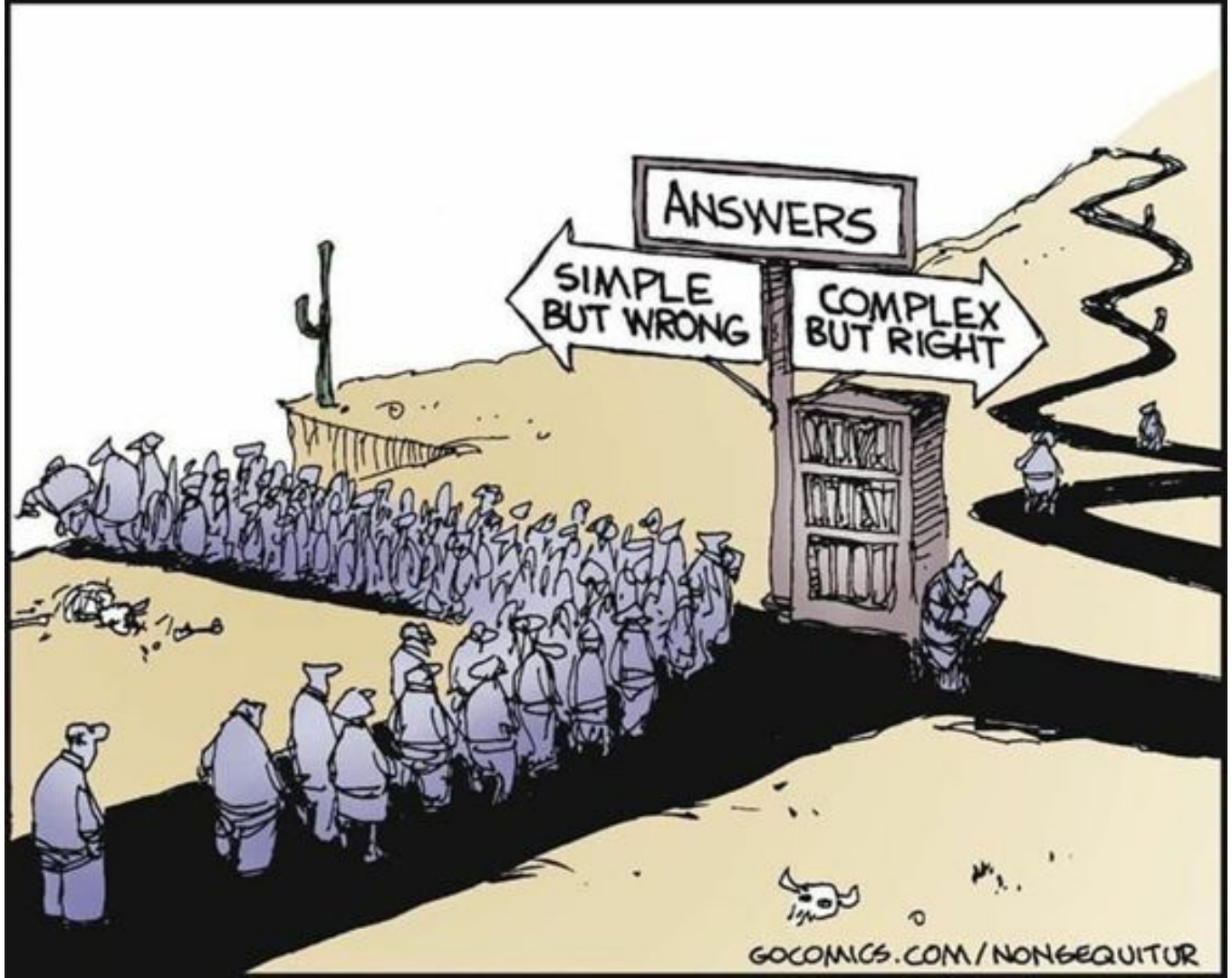
[i] Amazon has not stated that it will match its data center energy demand with real and additional renewable energy projects, and to-date has in part used lower-impact renewable energy credits to make its RE claims.

[ii] While Google has no public deadline, it aims to power its data centers with carbon-free energy 24x7.

[iii] Google stated it will no longer develop custom AI/ML solutions to facilitate upstream extraction.

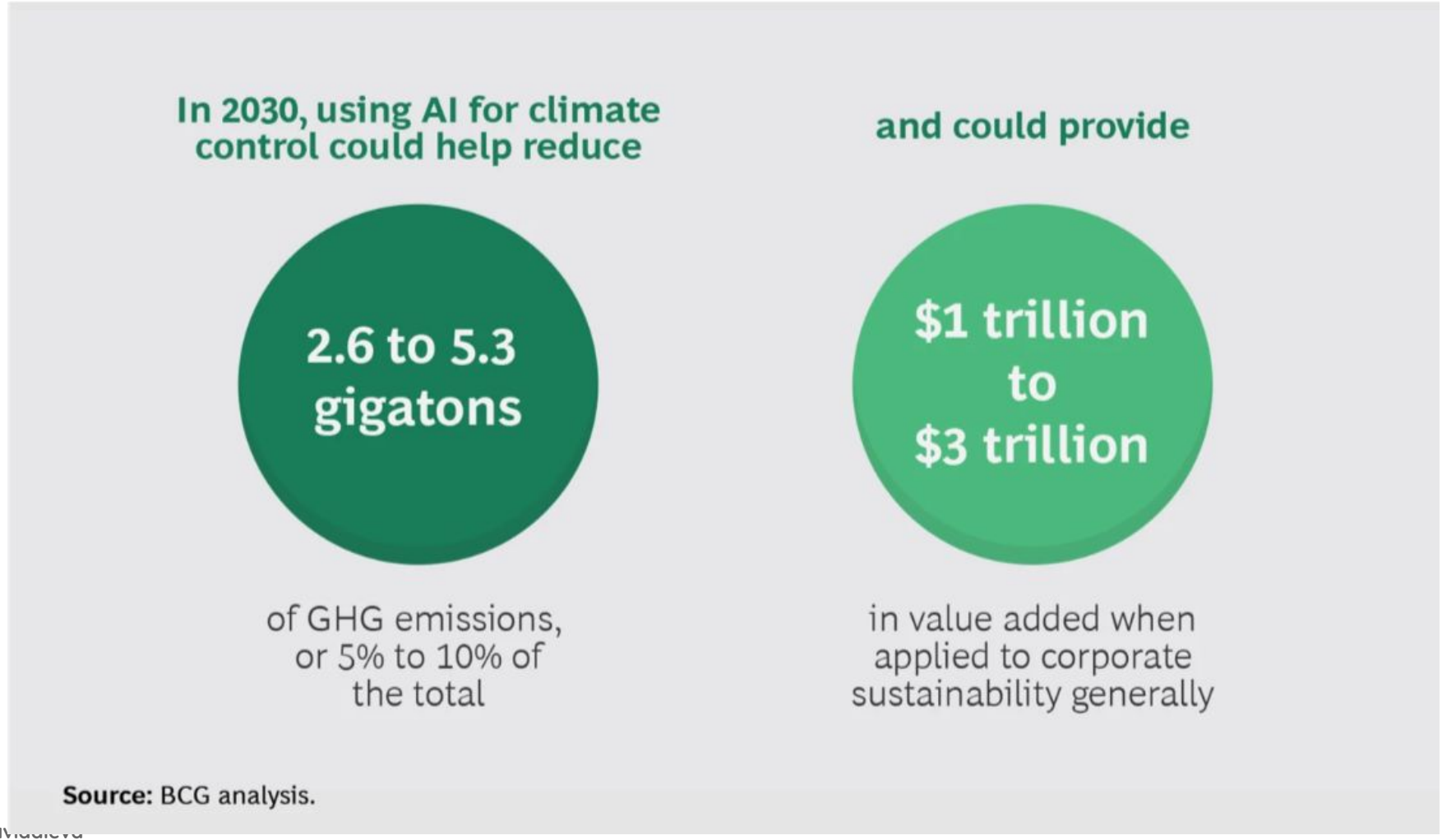
https://www.greenpeace.org/usa/reports/oil-in-the-cloud/


MIT Technology Review
Because technology is never really neutral.


ANSWERS
SIMPLE BUT WRONG
COMPLEX BUT RIGHT
GOCOMICS.COM/NONSEQUITUR

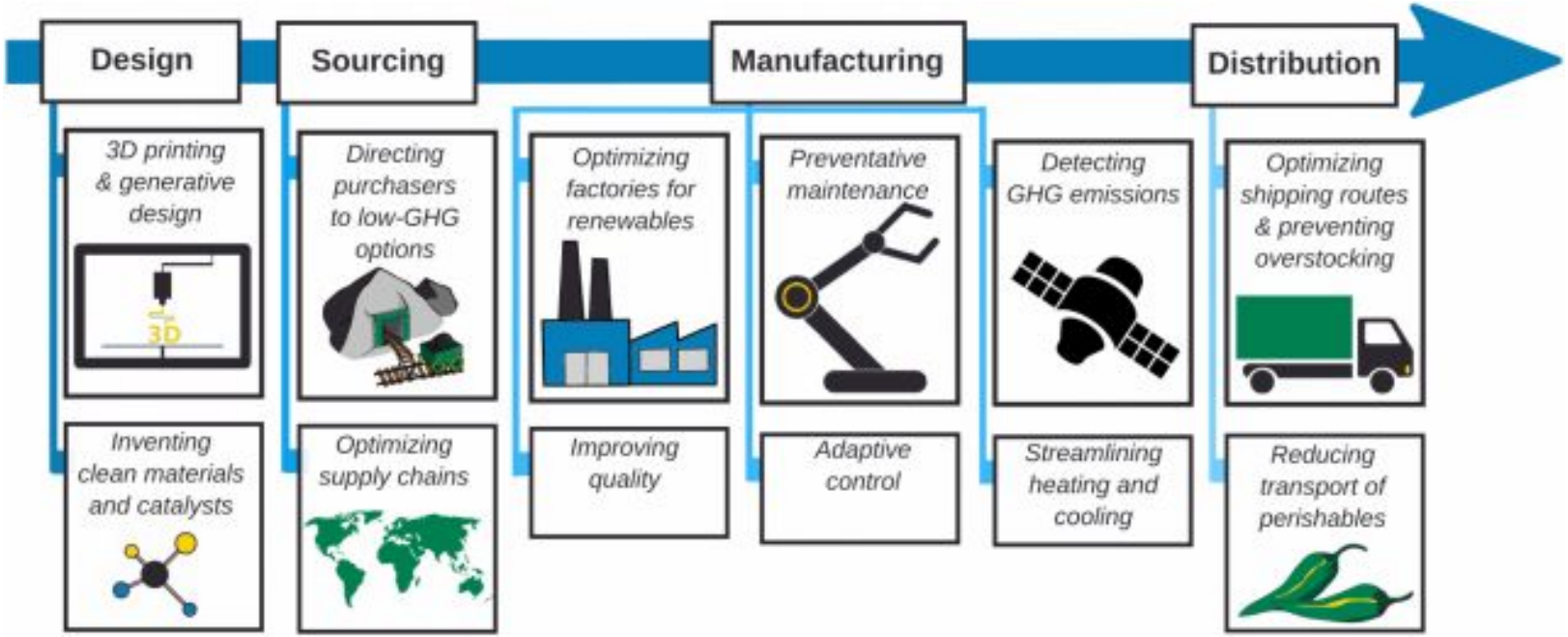
Opportunity Cost

Good News

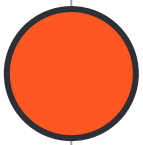

In 2030, using AI for climate control could help reduce
2.6 to 5.3 gigatons
of GHG emissions, or 5% to 10% of the total
and could provide
$1 trillion to $3 trillion
in value added when applied to corporate sustainability generally
Source: BCG analysis.

Monitoring Emissions.
Predicting Emissions.
Reducing Emissions.

Selected opportunities to reduce GHG emissions in industry using ML



Rolnick, David, et al. "Tackling climate change with machine learning." *ACM Computing Surveys (CSUR)* 55.2 (2022): 1-96.



And a lot more of good news!

Sustainability?

A **sustainable** future is one in which a

healthy environment,

economic prosperity,

and **social justice**

are pursued simultaneously to ensure the well-being and quality of life of present and future generations.

¡Gràcies!

¿Alguna pregunta?

@evavidaleva

eva.vidal@upc.edu